AD NUMBER

AD824300

LIMITATION CHANGES

TO:

Approved for public release; distribution is unlimited. Document partially illegible.

FROM:

Distribution authorized to U.S. Gov't. agencies and their contractors; Critical Technology; SEP 1967. Other requests shall be referred to Air Force Technical Application Center, VELA Seismological Center, Washington, DC. Document partially illegible. This document contains export-controlled technical data.

AUTHORITY

usaf ltr, 25 jan 1972

TECHNICAL REPORT NO. 67-63

OPERATION OF
THE TONTO FOREST SEISMOLOGICAL OBSERVATORY
Quarterly Report No. 3, Project VT/7702
1 July through 30 September 1967

GEOTECH
A TELEDYNE COMPANY

TECHNICAL REPORT NO. 67-63

OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

Quarterly Report No. 3, Project VT/7702
1 July through 30 September 1967

Sponsored by

Advanced Research Projects Agency
Nuclear Test Detection Office
ARPA Order No. 624

GEOTECH
A Teledyne Company
3401 Shiloh Road
Garland, Texas

30 October 1967

IDENTIFICATION

AFTAC Project No:	VELA T/7702
Project Title:	Operation of TFSO
ARPA Order No:	624
ARPA Program Code No:	
Name of Contractor:	Teledyne Industries Incorporated Geotech Division Garland, Texas
Date of Contract:	1 January 1967
Amount of Contract:	$1,090,300
Contract Number:	AF 33(657)-67-C-0091
Contract Expiration Date:	31 December 1967
Program Manager:	B. B. Leichliter, BR1-2561

CONTENTS

CONTENTS, Continued

ILLUSTRATIONS

ILLUSTRATIONS, Continued

****

TABLES

ABSTRACT

This is a report of the work accomplished on Project VT/7702 from 1 July through 30 September 1967. Project VT/7702 includes the operation, evaluation, improvement, and expansion of the Tonto Forest Seismological Observatory (TFSO) located near Payson, Arizona. It also includes special research and test functions carried out at TFSO and research and development tasks performed by the Garland, Texas, staff using TFSO data.

BLANK PAGE

OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

1. INTRODUCTION

1.1 AUTHORITY

The research described in this report was supported by the Advanced Research Projects Agency, Nuclear Test Detection Office, and was monitored by the Air Force Technical Applications Center (AFTAC) under Contract AF 33(657)-67-C-0091. The contract is dated 1 January 1967; the Statement of Work for Project VT/7702 is included as the appendix to this report.

1.2 HISTORY

The Tonto Forest Seismological Observatory (TFSO) was constructed by the United States Corps of Engineers in 1963. TFSO was designed to record seismic events and to be used as a laboratory for testing, comparing, and evaluating advanced seismograph equipment and seismometric recording techniques. The instrumentation was assembled, installed, and operated until 30 April 1965 by the Earth Sciences Division of Teledyne Industries under Contract AF 33(657)-7747. In March 1964, the Long-Range Seismic Measurements (LRSM) Program provided eight mobile seismic recording vans to extend the existing instrument arrays at TFSO. On 1 May 1965, Geotech assumed the responsibility for operating TFSO. The LRSM vans were phased out of the TFSO operation on 30 October 1965. On 1 January 1967, Contract AF 33(657)-67-C-0091 was awarded to Geotech for the operation of TFSO and the expansion of the TFSO seismograph array. The location of TFSO is shown in figure 1.

2. OPERATION OF TFSO

2.1 GENERAL

Data are recorded at TFSO on a 24-hour-a-day basis. The observatory is manned continuously. A full complement of personnel is on duty 8 hours a day, 5 days a week; at other times, a reduced operating crew is on duty.

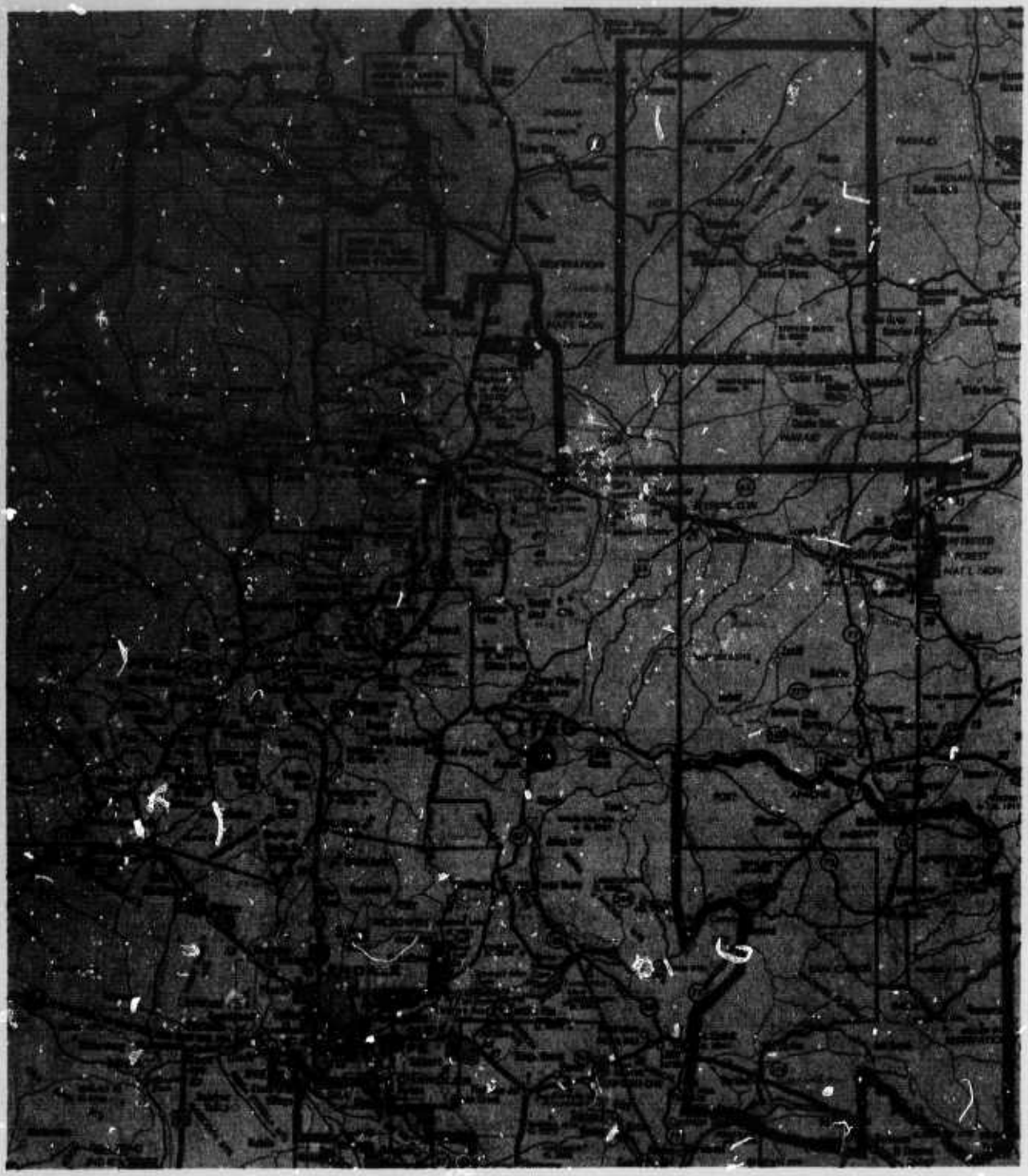

Figure 1. Location of TFSO

G 650

2.2 STANDARD SEISMOGRAPH OPERATING PARAMETERS

The operating parameters and tolerances for the TFSO standard seismographs are shown in table 1. Frequency response tests are made routinely, and parameters are checked and reset to maintain the specified tolerances.

Normalized response characteristics of TFSO standard seismographs are shown in figure 2. In addition to these standard seismographs, two filtered summation seismographs are recorded. A UED filter with a high-cut frequency of 1.75 cps with a slope of 24 dB per octave and a low-cut frequency of 0.7 cps with a slope of 24 dB per octave is used in the ΣTF seismograph. This seismograph is recorded on 16-millimeter film data trunks 1 and 7 and on magnetic-tape data trunks 2 and 5. A Krohn-Hite filter with the high-cut frequency set at 2.0 cps with a slope of 24 dB per octave and the low-cut frequency set at 1.0 cps with a slope of 24 dB per octave is in the ΣTFK seismograph which is recorded on 16-millimeter film data trunk 1.

2.3 DATA CHANNEL ASSIGNMENTS

Each data format recorded at TFSO is assigned a data group number. When a data format is changed, a new data group number is assigned. Several data format change notices reporting changes in channel assignments were submitted to the Project Officer and to frequent users of TFSO data during this reporting period.

2.4 COMPLETION AND SHIPMENT OF DATA

The magnetic-tape seismograms are shipped from TFSO each week. Three of the magnetic-tape recorders are used to record data for the AFTAC/VELA Seismological Center (VSC), and three magnetic-tape recorders are used to provide data to universities. When data from all three magnctic-tape recorders are not required by the universities, the observatory notifies VSC.

Film seismograms from 10 Develocorders are routinely shipped to data users. The film and magnetic-tape operation logs and calibration logs are copied and shipped with the seismograms. Copies of selected Develocorder data are sent to the Geotech Program Manager regularly and to other data users on special request. The shipments of 16-millimeter film seismograms routinely sent to the Seismic Data Laboratory (SDL) repository are complete through July 1967, except for selected seismograms being held for use in conjunction with special investigations or instrument tests that are in progress.

Table 1. Operating parameters and tolerances of standard seismographs at TFSO

Seismograph				Operating parameters and tolerances				Filter settings		
System	Comp	Type	Model	Ts	λs	Tg	λg	δ^2	Bandpass at 3 dB cutoff (sec)	Cutoff rate at SP side (dB/oct)
SP	Z	Johnson-Matheson	6480	1.25 ±2%	0.54 ±5%	0.33 ±5%	0.65 ±5%	0.0117	0.1 - 100	12
SP	H	Johnson-Matheson	7515	1.25 ±2%	0.54 ±5%	0.33 ±5%	0.65 ±5%	0.0117	0.1 - 100	12
SP	Z	Benioff	1051	1.0 ±2%	1.0 ±5%	0.2 ±5%	1.0 ±5%	0.0104	0.1 - 100	12
SP	H	Benioff	1101	1.0 ±2%	1.0 ±5%	0.2 ±5%	1.0 ±5%	0.0104	0.1 - 100	12
SP	Z	UA Benioff	1051	1.0 ±2%	1.0 ±5%	0.75	1.0 ±5%	0.0245		
SP	H	UA Benioff	1101	1.0 ±2%	1.0 ±5%	0.75	1.0 ±5%	0.0245		
SP	H	Wood-Anderson	TS 220	0.8	0.78					
IB	Z	Melton	10012	2.25 ±5%	0.65 ±5%	0.64 ±5%	1.2 ±5%	0.0006	0.05 - 100	18
IB	H	Lehner-Griffith	SH-216	2.25 ±5%	0.65 ±5%	0.64 ±5%	1.2 ±5%	0.0004	0.05 - 100	18
BB	Z	Press-Ewing	SV-232	12.0 ±5%	0.425 ±10%	0.64 ±5%	9.0 ±10%	0.00027	0.05 - 100	18
BB	H	Press-Ewing	SH-242	12.0 ±5%	0.425 ±10%	0.64 ±5%	9.0 ±10%	0.00027	0.05 - 100	18
LP[a]	Z	Geotech	7505A	20.0 ±5%	0.74 ±10%	110.0 ±10%	0.83 ±10%	0.66	25 - 1000	12
									20 - 200[c]	12
LP[a]	H	Geotech	8700C	20.0 ±5%	0.74 ±10%	110.0 ±10%	0.83 ±10%	0.66	25 - 1000	12
									20 - 200[c]	12
LP[b]	Z	Geotech	7505A	20.0 ±5%	0.74 ±10%	110.0 ±10%	0.83 ±10%	-	25 - 1000	12
LP[b]	H	Geotech	8700C	20.0 ±5%	0.620 ±10%	30.0 ±10%	0.591 ±10%	-	25 - 1000	12
									20 - 1000[c]	12

KEY

SP Short period
IB Intermediate band
BB Broad band
LP Long period
UA Unamplified (i.e., earth powered)

Ts Seismometer free period (sec)
Tg Galvanometer free period (sec)
λs Seismometer damping constant
λg Galvanometer damping constant
δ^2 Coupling coefficient

[a] Since March 1966
[b] Prior to March 1966
[c] With a 6-second notch filter

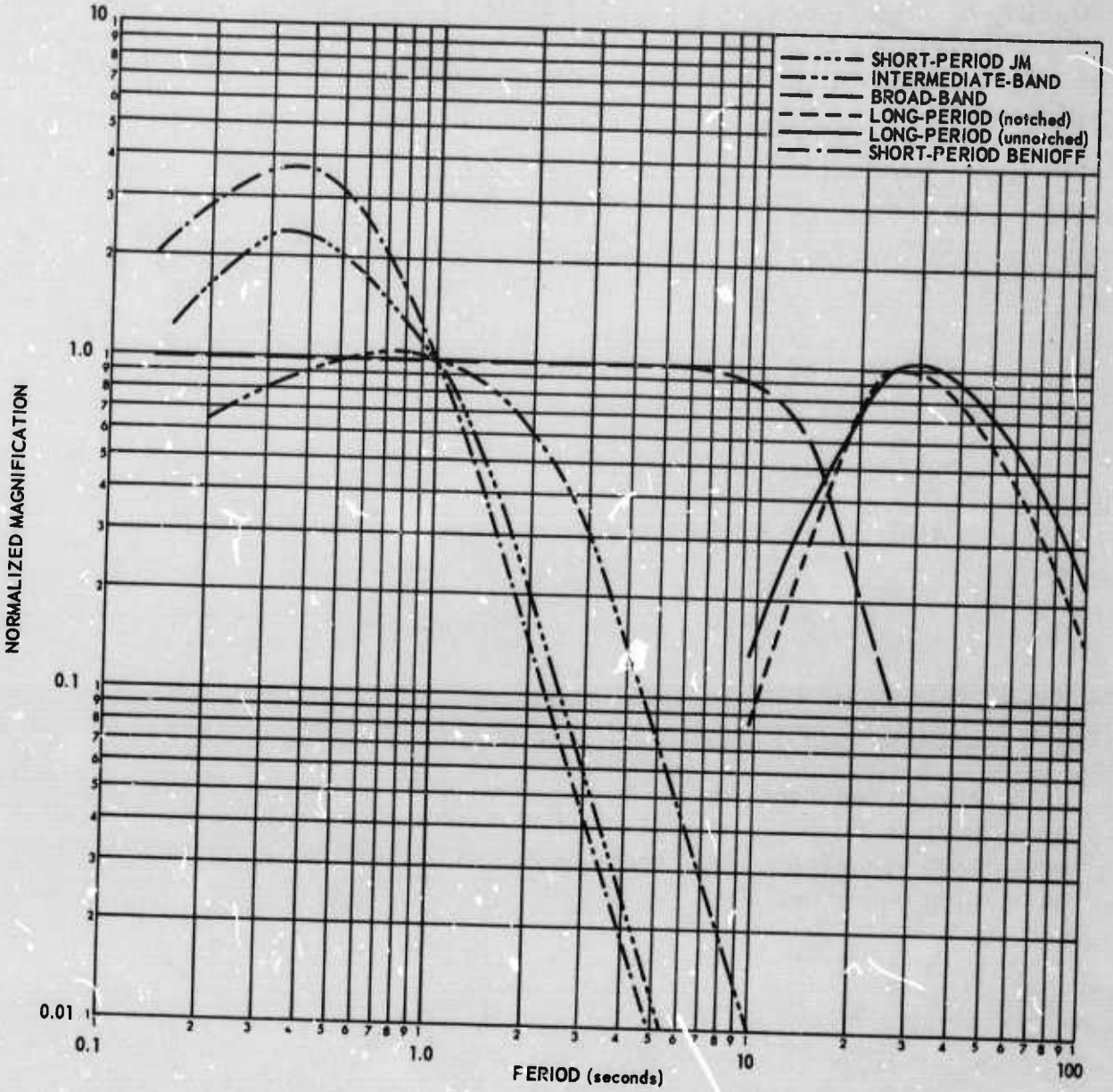

Figure 2. Normalized response characteristics of standard seismographs at TFSO

G 1418

2.5 QUALITY CONTROL

2.5.1 Quality Control of 16-Millimeter Film Seismograms

Quality control checks of randomly selected 16-millimeter film seismograms from data trunks 1, 2, and 8, and the associated operation logs are made in Garland. Items that are routinely checked by the Quality Control Analyst include:

a. Film boxes - neatness and completeness of box markings;

b. Develocorder logs - completeness, accuracy, and legibility of logs;

c. Film;

(1) Quality of the overall appearance of the record (for example, trace spacing and trace intensity);

(2) Quality of film processing;

d. Analysis - completeness, legibility, and accuracy of the analysis sheets.

Results of these evaluations are sent to the observatory for their review and comment.

2.5.2 Quality Control of Magnetic-Tape Seismograms

Routine quality control checks of randomly selected magnetic-tape seismograms were made in Garland and at TFSO to assure that recordings met specified standards. The following are among the items that were checked by the quality control group:

a. Tape and box labeling;

b. Accuracy, completeness, and neatness of logs;

c. Adequate documentation of logs by voice comments on tape where applicable;

d. Seismograph polarity;

e. Level of calibration signals;

f. Relative phase shift between array seismographs;

g. Level of the microseismic background noise;

h. Level of the system noise;

i. PTA dc balance;

j. Oscillator alignment;

k. Quality of the recorded WWV signal where applicable;

l. Time-pulse carrier;

m. Binary coded digital time marks.

2.6 U. S. AIR FORCE SURVEY TEAM

Members of the U. S. Air Force 1381st Geodetic Survey Squadron, Warren Air Force Base, Cheyenne, Wyoming, began arriving at TFSO on 10 August 1967. The team was headed by Mr. Thomas A. Perrott, and included 2nd Lieutenant Roy Herbst and six airmen. These personnel will be on site until about 15 October 1967 to accomplish a final coordinate survey of locations within the expanded short-period and new long-period arrays.

2.7 SMALL BUSINESS ADMINISTRATION VISIT

Mr. C. P. Fink of the Phoenix office of the Los Angeles Defense Contract Administration Services Region (DCASR), visited TFSO on 12 July 1967. The visit was in compliance with the regulations of the Small Business Administration.

2.8 SECURITY INSPECTION

Mr. M. L. Craig, Industrial Security Chief from Phoenix, Arizona, made a routine security inspection of the observatory on 19 September 1967. All security procedures were found to be in order. Our vault was inspected and certified to meet the requirements for classified document storage which go into effect on 1 March 1968.

2.9 EMERGENCY POWER GENERATOR

The emergency power generator was operated almost daily during this reporting period. All but a very few hours of operation were necessary because of heavy storm activity resulting in commercial power fluctuations and outages.

3. EVALUATE DATA AND DETERMINE OPTIMUM OPERATIONAL CHARACTERISTICS

3.1 MODIFICATIONS TO TFSO INSTRUMENTATION

3.1.1 Deletion of Elements from the 31-Element Array

On 8 August 1967, operation of six of the remaining eight elements of the original 31-element array was discontinued. The field cables from these elements have been retrieved and tested, and the seismometers have been modified and checked in preparation for their installation in the 37-element expanded array. Figure 3 shows the locations of the systems currently being operated.

3.2 MAINTENANCE OF TFSO EQUIPMENT

3.2.1 Spiral-Four Cable Replacement

Lightning damage and vandalism increased spiral-four cable replacement during this reporting period. Four 1/4-mile lengths were either cut or shot. To date, fourteen 1/4-mile lengths have been damaged by lightning; in some cases, the cable was physically blown apart. The vandalism problem was reported to the Phoenix office of the FBI. Mr. Grady, Special Agent, was briefed at the observatory on 28 September. He suggested that an article appear in the local newspaper for the next two or three weeks and that signs be posted in trouble areas regarding government property and penalities resulting from thievery or destruction. He said that we should notify him at once if the vandalism continues or increases.

3.3 MAINTAIN TFSO FACILITIES

3.3.1 Station Storm Damage

Lightning damage to station equipment or facilities during this report period included a water circulating pump in the air conditioning system, two 440-volt circuit breaker units, and the station commercial power 75 kVA transformer. All units have been repaired or replaced.

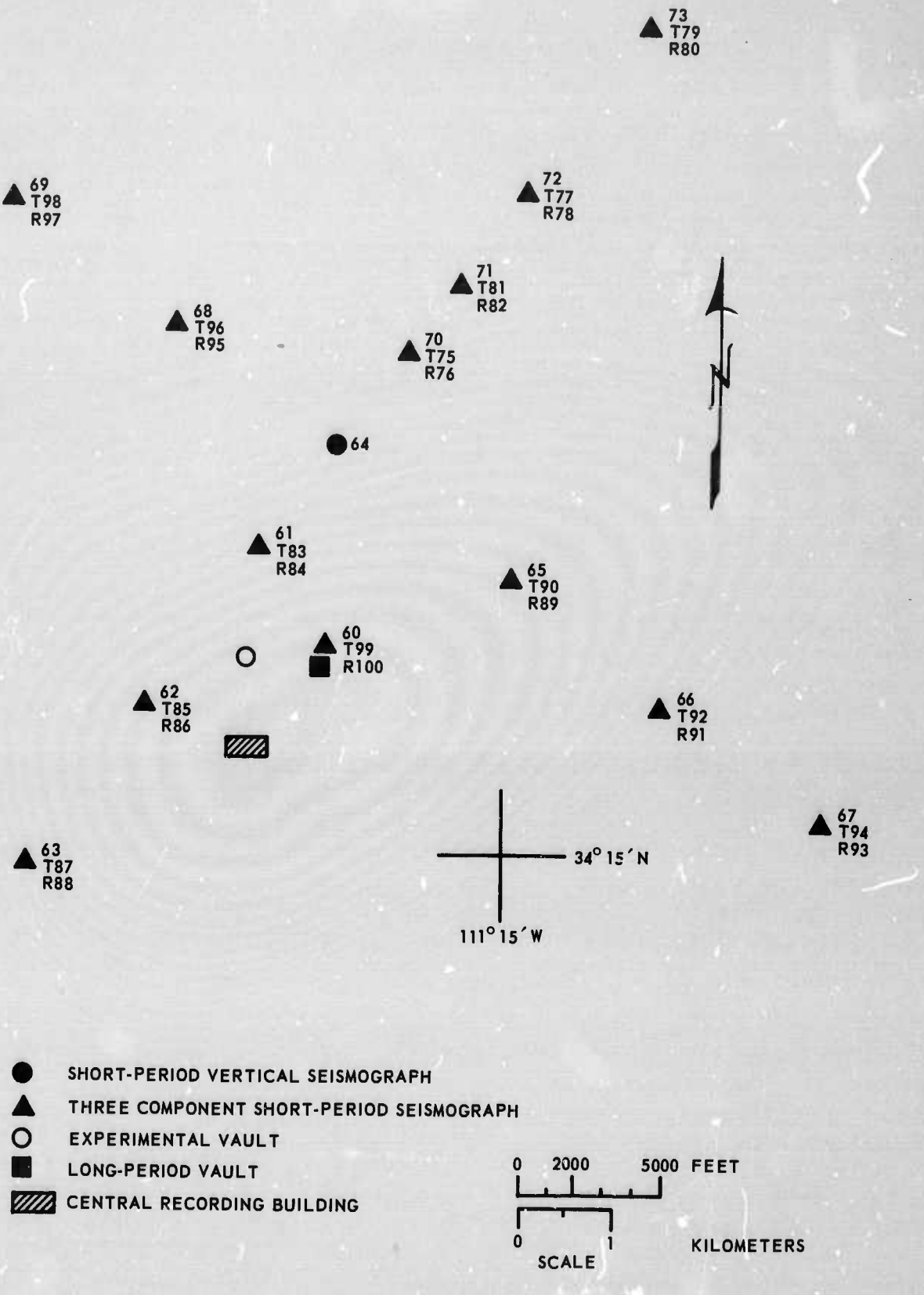

Figure 3. Tonto Forest Seismological Observatory vault locations, 30 September 1967

G 2918

4. ANALYZE DATA

4.1 DAILY REPORTS TO THE COAST AND GEODETIC SURVEY

TFSO reports the arrival time, period, and peak amplitude of events recorded at TFSO to the Director of the Coast and Geodetic Survey (C&GS) in Washington, D. C., daily. The number of events reported by TFSO during each month of the reporting period is shown in table 2, by type.

Table 2. Events reported to the C&GS by TFSO during July, August, and September 1967

Month	Local	Near Regional	Regional	Teleseisms	Total
July	32	188	44	1078	1342
August	19	128	16	903	1066
September	16	236	12	902	1166

The number of events reported by the C&GS in their "Earthquake Data Report" for March, April, and May 1967, are given in table 3. Also shown in table 3, by month, are the percentages of the C&GS hypocenters within 100 degrees of TFSO in which TFSO data were used to establish the location; the percentages of the C&GS hypocenters from which TFSO recorded a P or PKP phase, based on ABP associated data; and the percentage of events from which TFSO recorded a P, PKP, or later phase, based on updated ABP associated data.

Figures 4 and 5 show the world-wide distribution of the C&GS located epicenters for March, April, and May. The three types of symbols used to show the epicentral locations represent the detection, by TFSO, of a P or PKP phase, the detection of an event in which the first recorded arrival was not P or PKP, and no detection by TFSO.

4.2 DAILY ANALYSIS FOR MULTISTATION EARTHQUAKE BULLETIN

Data from TFSO are combined with data from CPSO, BMSO, UBSO, and WMSO and published in a monthly multistation earthquake bulletin. The bulletins for April and May 1967 were published during this reporting period, and the ABP output for June was received near the end of September. Raw data for June, July, and August 1967 were transcribed onto digital magnetic-tape and sent to SDL for processing. Keypunching of the September raw data is about 40 percent complete.

Table 3. Hypocenters reported by C&GS and percentages of located events recorded by TFSO during March, April, and May 1967

Month	Percentage of events located using TFSO data $\Delta \leq 100^{\circ}$	Percentage of located events from which P or PKP recorded	Percentage of located events from any phase recorded	Number of hypocenters located
March	74.5	72.5	77.1	411
April	61.3	66.9	73.2	427
May	60.7	65.1	71.5	413

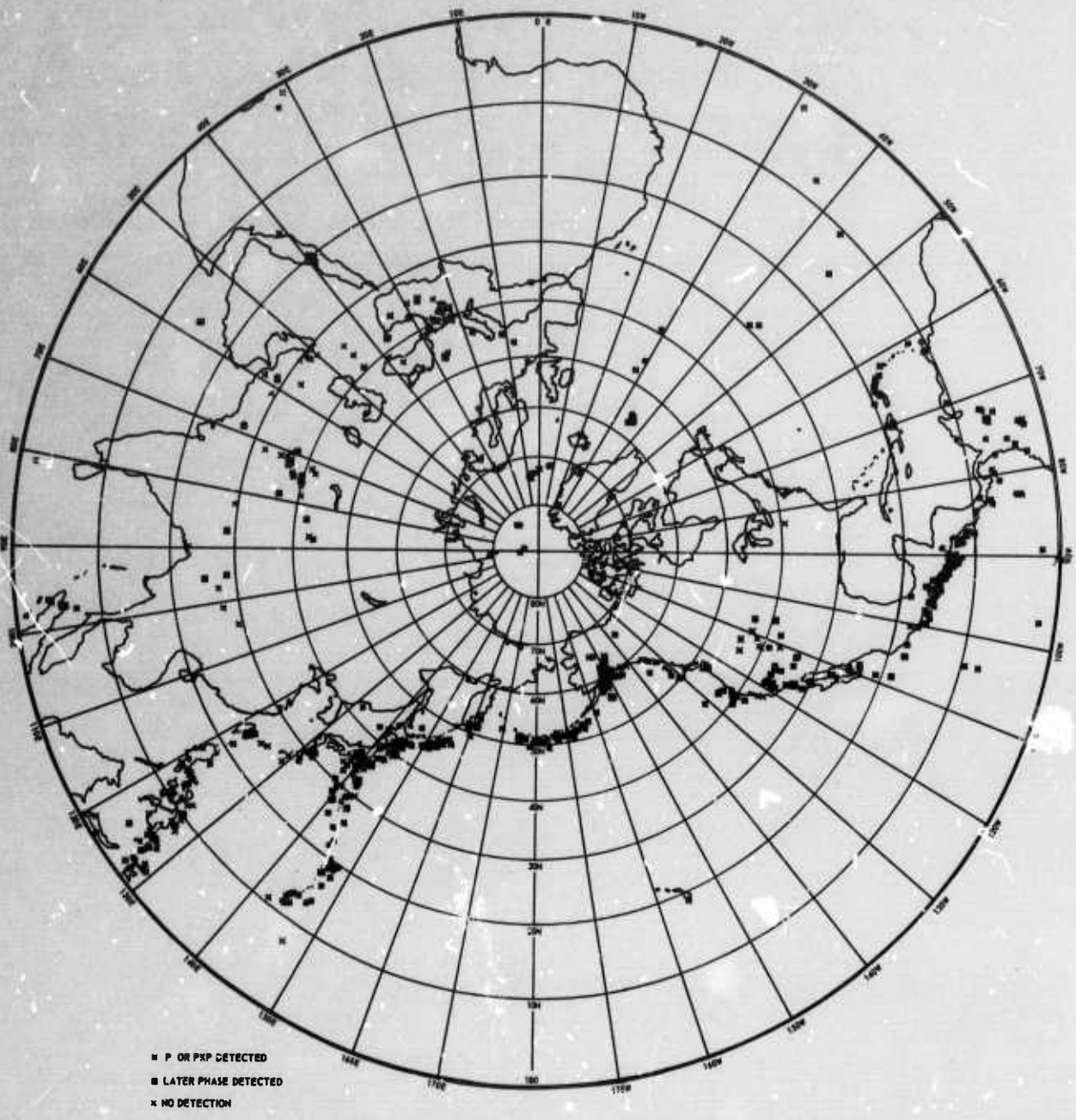

Figure 4. Distribution of Coast and Geodetic Survey located epicenters in the northern hemisphere for March, April, and May 1967

G 3179D

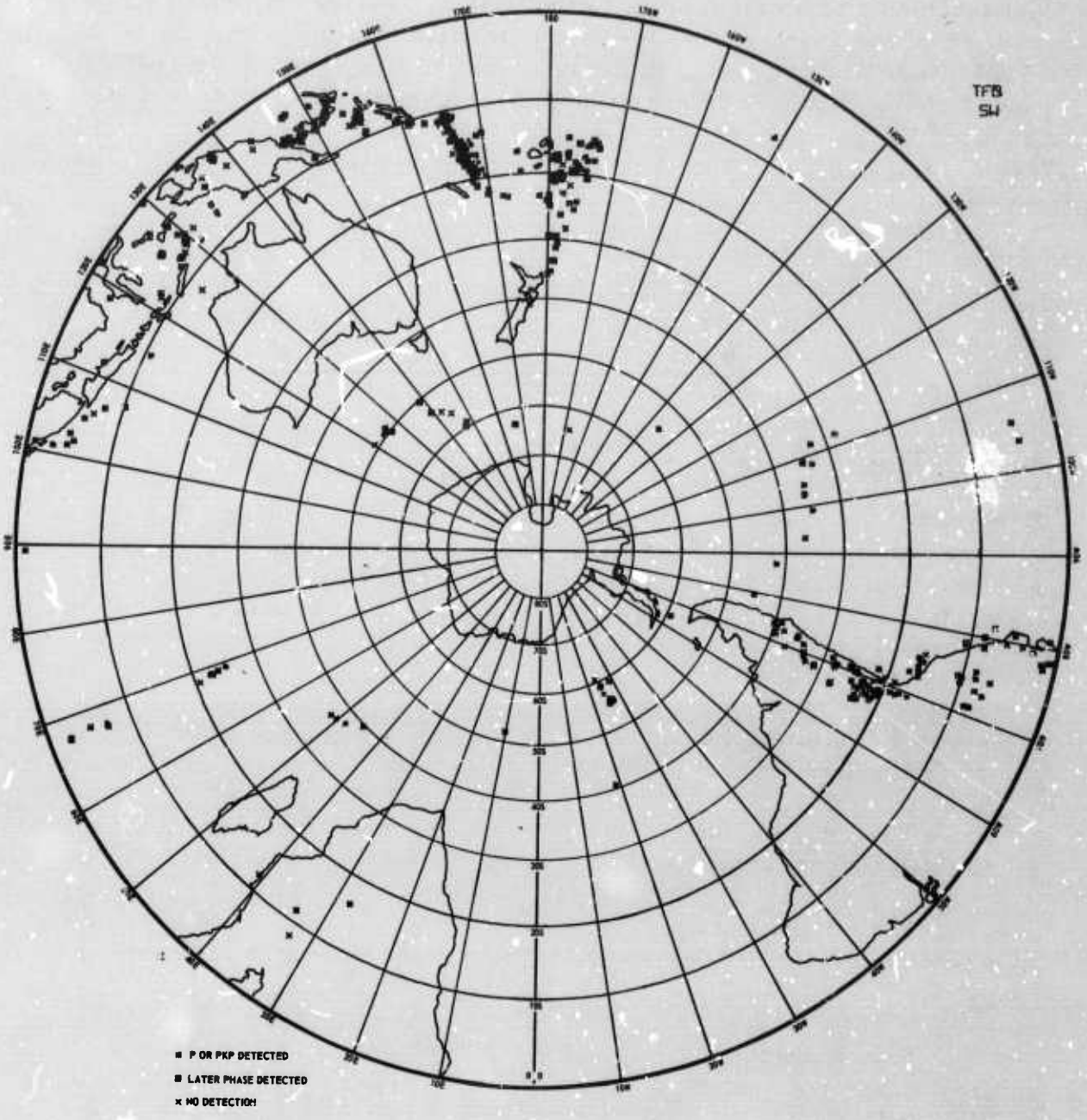

Figure 5. Distribution of Coast and Geodetic Survey located epicenters in the southern hemisphere for March, April, and May 1967

G3180D

4.3 ROUTINE NOISE SURVEY

Measurements of ambient noise in the 0.4- to 1.4-second period range are made from the short-period 16-millimeter film seismograms daily, at TFSO. Data are processed in Garland, and monthly cumulative probability curves of trace amplitude and ground displacement as recorded on the Z60, ΣT, and ΣTF seismograms are published. Curves for the months of June, July, and August 1967 were sent to the Project Officer during this reporting period.

5. PROVIDE OBSERVATORY FACILITIES AND ASSISTANCE TO OTHER ORGANIZATIONS

5.1 ASTRODATA DATA ACQUISITION SYSTEM

Extensive modifications on the Astrodata seismic data acquisition system designed to increase the recording time per reel of tape to about two hours and twenty minutes, twice the original recording time, were made during this reporting period. This was accomplished by decreasing the number of data channels recorded from 96 to 48 and by decreasing the tape speed by a factor of two.

Each of the following changes were either desired or necessary to accomplish the modifications economically:

a. The total recording time per reel has been doubled to 2 hours and 20 minutes without changing the bit density of 556 bpi.

b. Each record now has 220 scans of each of 48 channels, sampling at a rate of 20 samples per second. Each record is exactly 11 seconds long.

c. Scans are now initiated alternately at 48- and 52-millisecond intervals, and the total time required for each 48-channel scan is 3 milliseconds.

d. The digital clock now runs at a basic rate of 500 cps. This doubles the capacity of the clock to 37 hours, 16 minutes, and 57.726 seconds. The 26 bits time information must be evaluated using the following bit values:

2^{26}, 2^{25}, 2^{24}, 2^{23}, ----------2^{3}, 2^{2}, 2^{1} milliseconds

The most significant bit is now 2^{26} milliseconds instead of 2^{25} milliseconds, and the least significant bit is now 2^{1} milliseconds instead of 2^{0} milliseconds.

Revisions of the logic (including the addition of several logic cards), adjustment of delays throughout the system, and revision of the Datamec tape recorder read and write electronics to accomodate the new tape speed were required. An alignment tape was used to adjust the Datamec transports. All changes have been documented and added to the Astrodata manuals. Test tapes have been made and are being evaluated in our Garland laboratory and at SDL to check the operation of the modified system.

5.2 RECORDINGS FOR THE CALIFORNIA INSTITUTE OF TECHNOLOGY

All 16-millimeter film seismograms recorded under data group 7211 were sent to the California Institute of Technology (Cal Tech), weekly, except for data requested by VSC.

5.3 TELEMETRY TO MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Telemetry of seven seismograph channels to Lincoln Laboratory, Massachusetts Institute of Technology (MIT), continued throughout this reporting period. MIT is notified in advance when the seismographs are attenuated for special tests.

5.4 ASTROGEOLOGICAL DEPARTMENT OF THE U. S. GEOLOGICAL SURVEY

TFSO has continued to support Dr. Harold Krivoy of the Astrogeological Department of the United States Geological Survey (USGS) in Flagstaff, Arizona. Dr. Krivoy receives copies of the daily station message, routinely, and prints of events of special interest are sent to him when requested. Dr. Krivoy requested and received authorization to receive all TFSO Helicorder records, not needed by the observatory, on a regular basis. This will be started about 1 October 1967.

5.5 VISITORS

5.5.1 Visits by School Groups

Arizona State University students and instructors visited TFSO on 7 July. Approximately 64 visitors were given tours of the observatory and brief lectures on seismology.

5.5.2 Teledyne Visitors

Mr. Martin Robinson, Program Engineer, visited the station from 15 through 22 August for the purpose of testing new lightning protection circuitry for the 37-element array.

Mr. Arnold Sisson, Program Engineer, visited the station from 5 through 8 September for the purpose of general orientation.

5.5.3 Visits by Project Managers

Dr. Frank Pilotte, VSC; Mr. J. M. Whalen, Geotech Geophysical Operations Department Manager; and Mr. B. B. Leichliter, Geotech Project VT/7702 Program Manager, visited TFSO on 26 and 27 July 1967.

Dr. Frank Pilotte, VSC, and Mr. Don Clements, ARPA, visited TFSO on 13 September 1967.

Captain Munzlinger, VSC Project Officer, and Mr. B. B. Leichliter, Geotech Program Manager, visited TFSO from 25 through 27 September 1967. During each of these visits the status of current work was reviewed, and future work of Project VT/7702 was planned.

5.5.4 Naval Officers' Visit

Twelve Naval Intelligence Officers from Phoenix, Arizona, visited the station on 8 July 1967. A tour was arranged and brief discussions held on instrumentation, engineering, and seismology.

5.5.5 Geodetic Survey Personnel

Mr. L. H. Schrag and Mr. R. S. Keenan, 1381st Geodetic Survey Squadron, USAF, Warren AFB, Cheyenne, Wyoming, were visitors at TFSO on 6 and 7 July 1967. The purpose of the visit was to coordinate the new short- and long-period array surveys with TFSO personnel.

5.5.6 Museum of Northern Arizona

Dr. E. B. Danson, Mr. Alexander Lindsey, and Mr. Roger Kelly, archeologists from the Museum of Northern Arizona, visited the station on 18 August. The TFSO array projects were discussed from an archeological viewpoint, and plans were made concerning future work.

5.5.7 India Atomic Energy Research Visit

Mr. T. G. Varghese, Atomic Energy Commission, Bombay, India, was a visitor at TFSO on 21 and 22 September. Mr. Varghese was given a tour of

the observatory and facilities, and many aspects of observatory operation and array installation techniques were discussed.

6. RESEARCH PROGRAMS

6.1 TESTS OF THE PERFORMANCE OF LONG-PERIOD SEISMOMETERS HOUSED IN AN EVACUATED SPHERICAL CHAMBER

Tests of the operational characteristics of long-period seismometers housed in an evacuated environment were continued during the reporting period. The seismometers, housed in the evacuated sphere-housing for the ocean-bottom seismograph on loan from Texas Instruments, were subjected to heat-cycling; the sphere-housing was heated locally, and the sphere was subjected to artifically-induced air circulation.

The tests of the operation of seismometers housed in the sphere with the sphere installed in the pier room were completed. Initially, we planned to transfer the sphere from the pier room to the surface adjacent to the walk-in vault and compare the operation of seismometers housed in the sphere to the operation of seismometers housed in near-surface tank vaults. Based on the results of the tests conducted to date, however, we do not plan additional testing of this system. A letter-type report of the tests is being prepared and will be submitted to the Project Officer when it has been completed.

6.2 EVALUATION OF LONG-PERIOD SOLID-STATE AMPLIFIER MODEL 28450-02

Tests of the Model 28450-02 long-period solid-state amplifier, started in June, were continued during the reporting period. Throughout much of the reporting period, difficulties were encountered with faulty components in the preamplifier portion of the Model 28450 amplifier; however, by the end of the period these problems had been solved, and the test seismograph was operating properly.

The field tests, to date, have shown the noise level of the Model 28450-02 amplifier to be equivalent to between 5 and 10 millimicrons within the frequency band of interest. This is not as good as the noise level obtained during the laboratory tests conducted in Garland (between 3 and 5 millimicrons); however, the noise level of the solid-state amplifier obtained in the field is comparable to the noise level of the Model 5240A PTA as normally operated in the field. Figure 6 is a representative, experimental seismogram from TFSO showing the noise level of the dummy-loaded long-period seismograph using the Model 28450-02 amplifier. This seismogram was selected from a series of figures

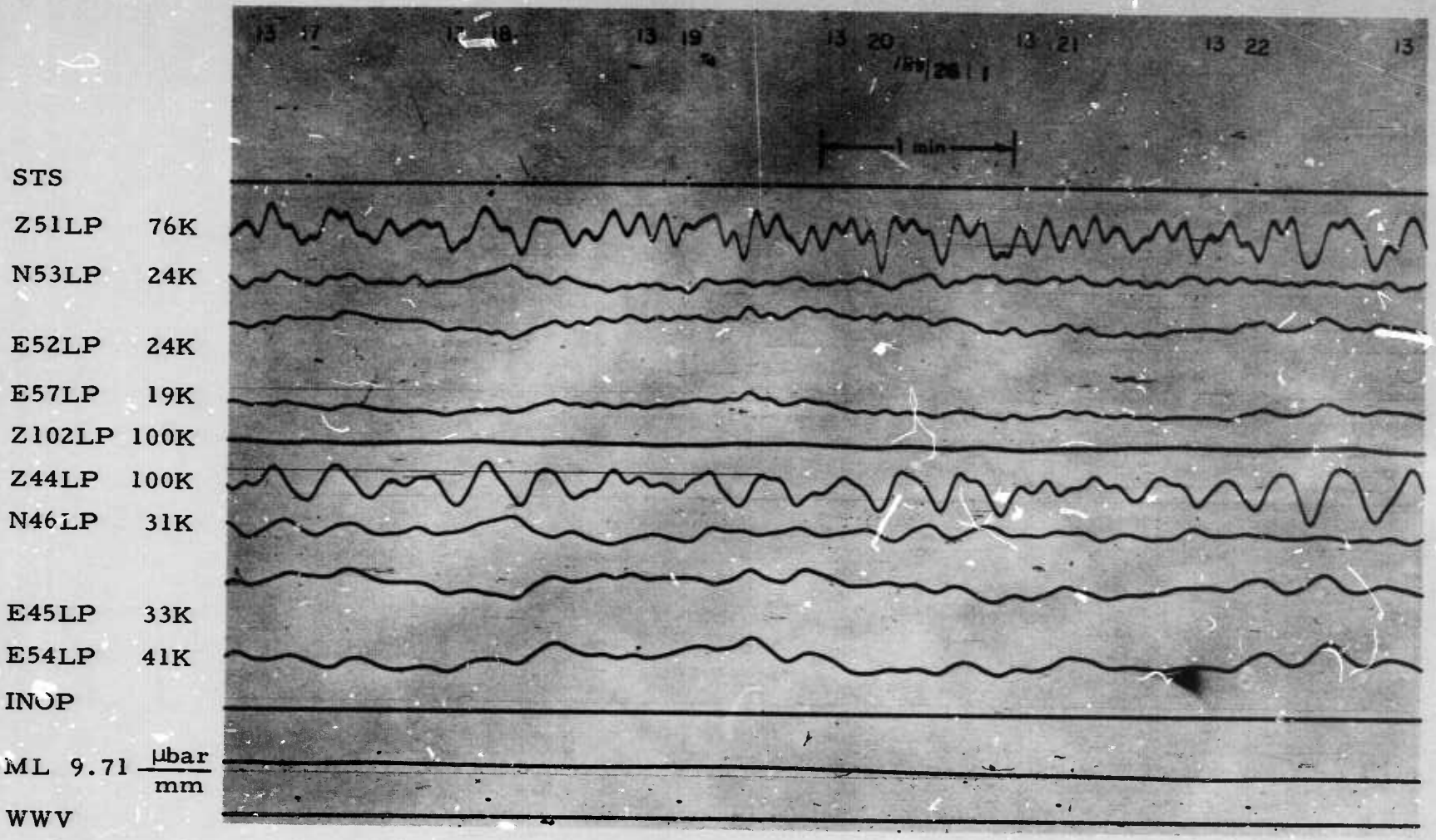

Figure 6. TFSO long-period experimental seismogram showing the noise level of a dummy-loaded long-period seismograph using the Model 28450-02 long-period solid-state amplifier (Z102LP) and operated at an equivalent magnification of 100K at 0.04 cps. (X10 enlargement of 16-millimeter film)

TFSO
18 Sept. 1967
RPN 261
DT LP EXP

covering a continuous 2-hour segment of test data being prepared for submittal to the Project Officer. The amplitude response and block diagram of this seismograph are shown in figures 7 and 8.

6.3 DESIGN AND INSTALL A SHORT-PERIOD ARRAY

6.3.1 Archeological Control

Archeological inspection of the expanded array was completed on 18 August 1967. Mr. Roger Kelley, Associate Professor of Archeology, has given clearance for all sites and cable trails. A final report is being written by the staff of Arizona Northern University.

6.3.2 Site Selection

Sites selected and trails flagged during this reporting period included Z6, Z7, Z13, Z14, Z15, Z16, Z17, Z18, Z33, Z34, Z35, and Z36. All sites and trail preparation for the short-period array have been completed. Figure 9 shows the array orientation, the vault location, cable trail location, and cable trail and vault construction status at the end of the reporting period.

6.3.3 Site and Road Construction

Magini Construction Company of Phoenix, Arizona, completed all trail and site construction work on 8 September 1967. The U. S. Forest Service has completed a report on necessary maintenance and rehabilitation work that in their opinion should be accomplished; this includes reseeding of roads and sites. TFSO does not yet have a copy of this report; however, the Forest Service would undertake this work under a contract with either Geotech or the United States Air Force.

6.3.4 Operational Status

Lightning problems slowed instrument installation during August and September. After the installation of the first five sites of the short-period array we found that the instruments were not adequately protected at the seismometer vaults from current surges due to lightning. On several occasions, the Model 25220 amplifiers were damaged as the result of lightning activity. The damage was confined to the voltage regulator section of the amplifier and to the input stage of the preamplifier. To provide additional lightning protection for these circuits, two 1.0 millihenry coils were connected in series in the data lines and 0.02 microfarad capacitors were connected between each side of the data line and ground (see figure 10). This additional protection proved to be adequate for protecting the voltage regulator, but when severe lightning discharges occurred we found that the preamplifier was still not adequately protected. The path for the discharges resulting in damage

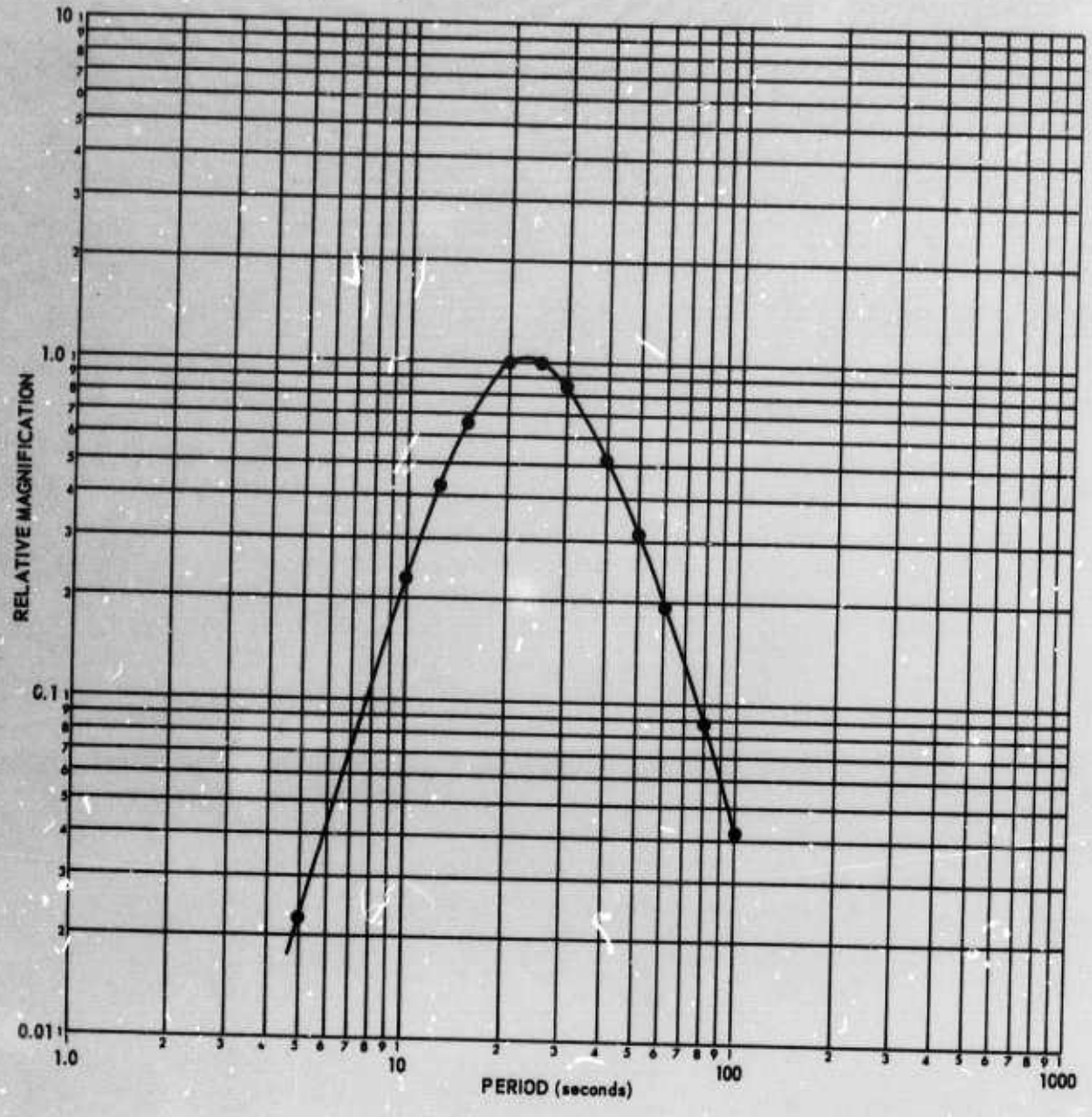

Figure 7. Frequency response for the long-period seismograph utilizing the Model 28450-02 amplifier

G 2925

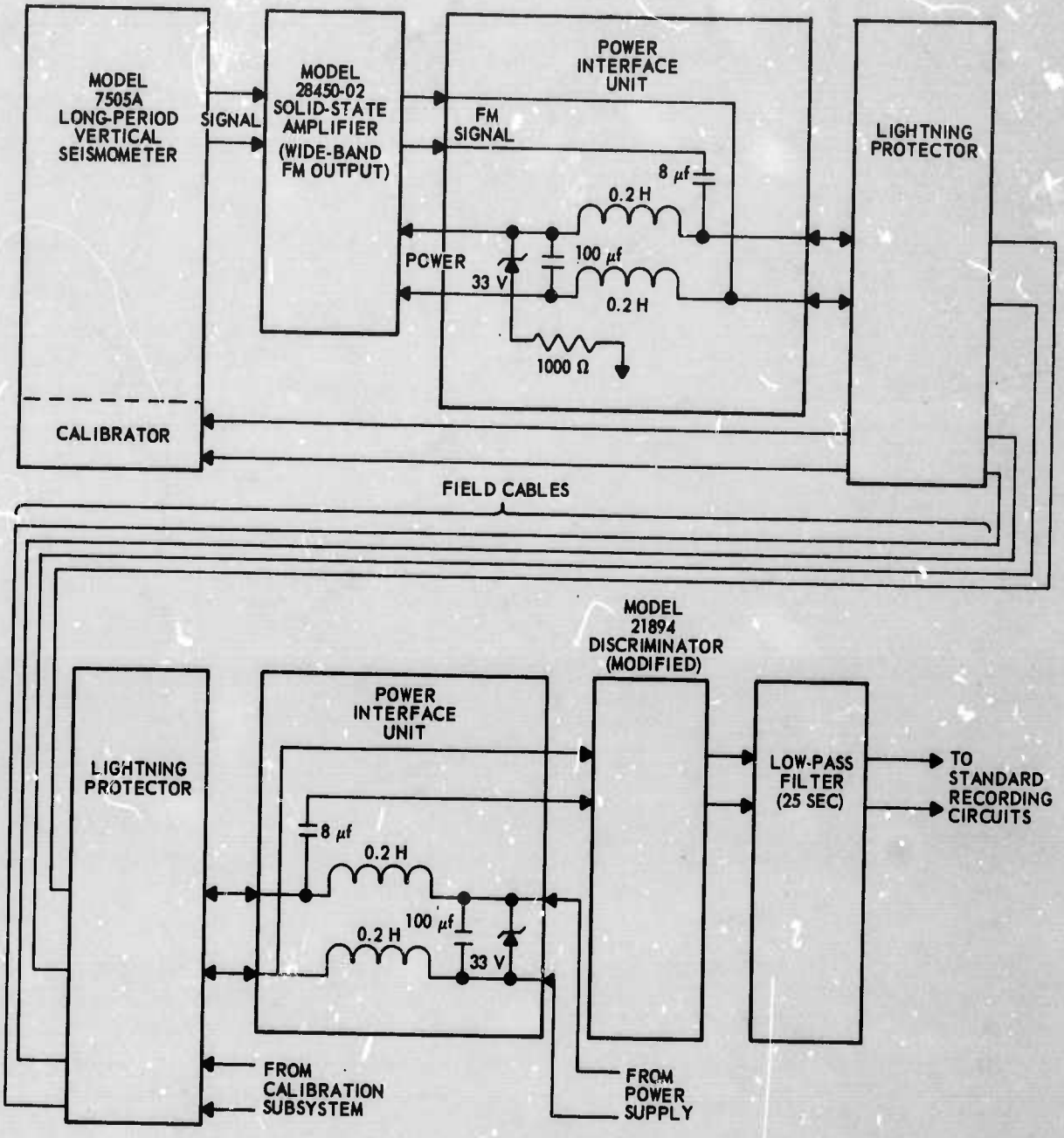

Figure 8. Simplified block diagram of the long-period system with a solid-state amplifier (Z102LP) being tested at TFSO

G 2924

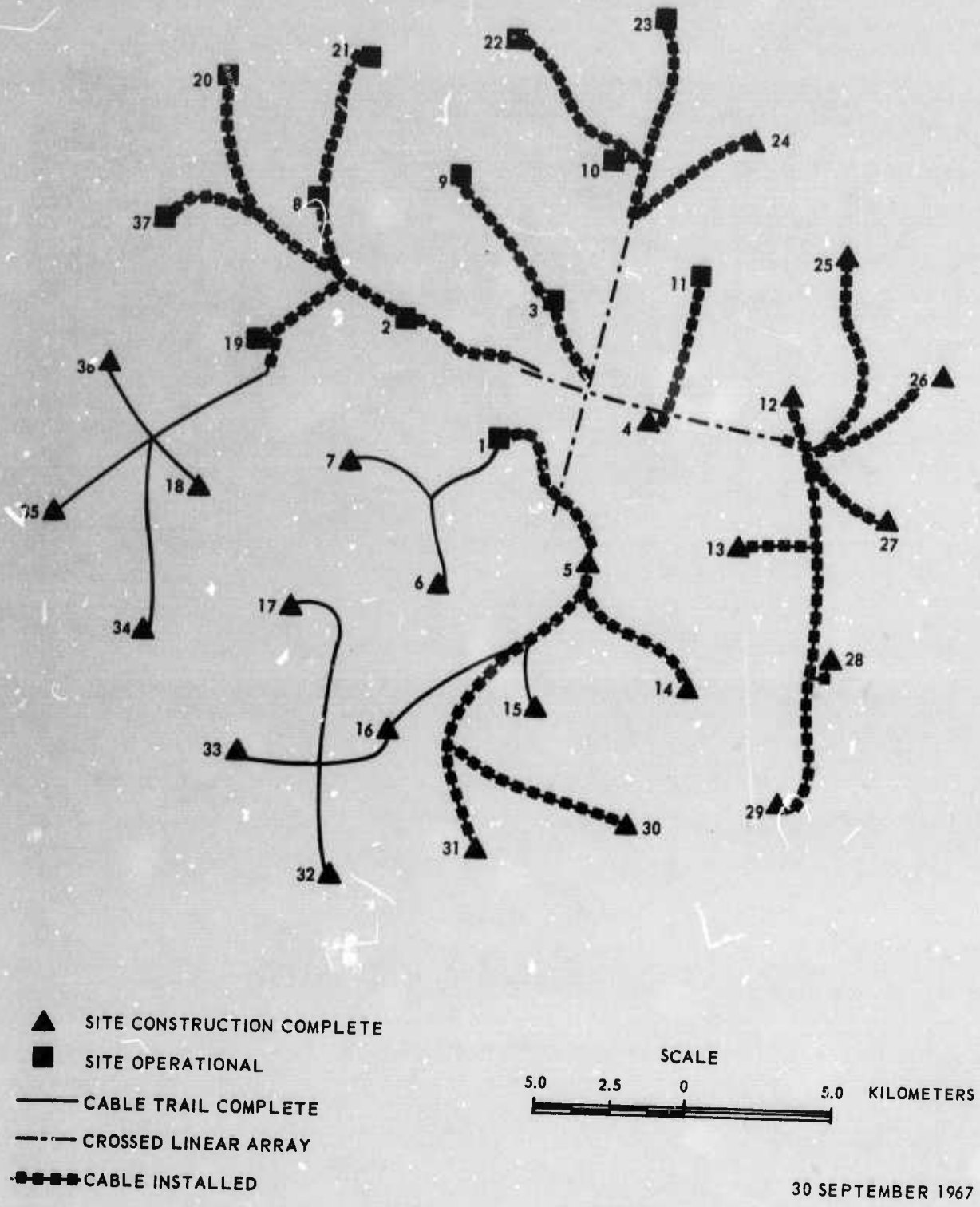

Figure 9. Plan of the 37-element array showing the locations of the sites, cable trails, and cable trail construction status

G 2796

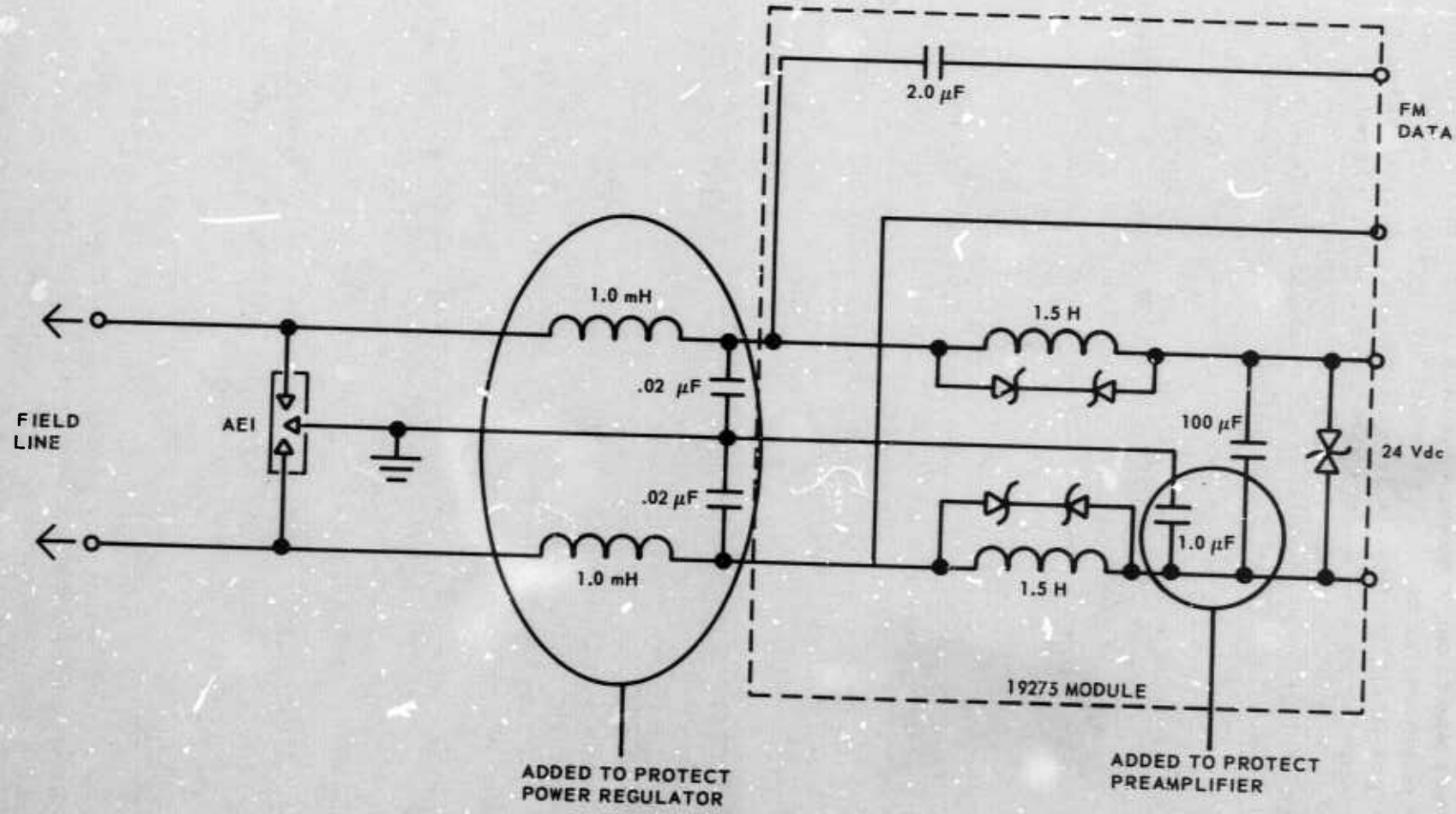

Figure 10. Portion of the lightning protection system installed at the seismometer vaults of the 37-element short-period array at TFSO

G 3224

to the preamplifiers was found to be the capacitance between the seismometer data coil and the seismometer case. To protect the preamplifier from the effects of discharges along this path, a 1.0 microfarad capacitor was added to the circuit between the negative side of the power line and ground, as shown in figure 10. In addition, the AEI lightning protectors were moved from the junction box located adjacent to the vault to the module assembly located inside of the vault to reduce the resistance in the ground buss to the protectors.

Several lightning storms have been encountered since the lightning protection system was modified. Figures 11 and 12 show the effects of an electrical storm on the data traces protected by the modified lightning system. No lightning damage has occurred to the seismographs protected by this modified system.

At the end of September 13, systems were operational, and cable installation had been completed to 27 of the 37 seismometer locations. We estimate that approximately 10 percent more cable will be required than originally planned.

High-impedance coils have been installed in all Johnson-Matheson vertical seismometers to be used in the 37-element array.

6.4 DESIGN AND INSTALL A LONG-PERIOD ARRAY

6.4.1 Land Permitting

The United States Corps of Engineers Phoenix real estate office received the Air Force land request on 28 August. A meeting was held between personnel of the Corps of Engineers and TFSO personnel shortly thereafter. On 6 September, all maps, specifications, and updated information for the long-period array were forwarded to the Corps of Engineers so that a Special Use Application could be submitted to the Forest Service. At the end of the reporting period, the Air Force land request was still pending.

6.4.2 Archeological Control

Site LP5 has been inspected and approved by Mr. Roger Kelley of Arizona Northern University. Inspection and approval of the other long-period sites will be accomplished during October and November.

6.4.3 Site Selection

Figure 13 shows the array progress at the end of September. Final selection of sites LP4, LP5, and LP7 was accomplished. Site LP4, located near Young, Arizona, has been selected as the site for the shallow hole installation. A preliminary shallow refraction survey using a Dyna Metric Model 117

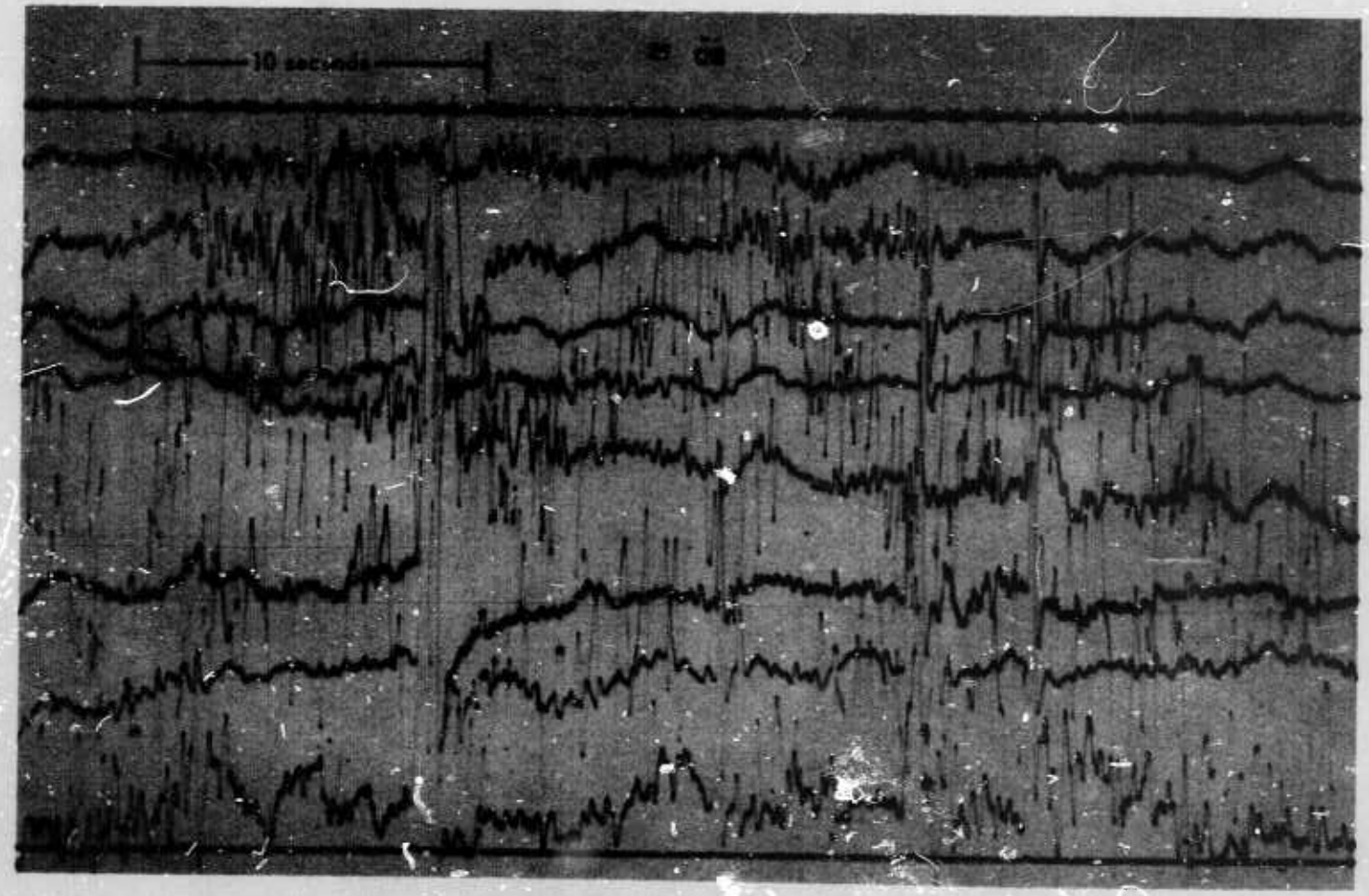

Figure 11. TFSO short-period seismogram illustrating the effects of lightning on the seismographs of the 37-element array protected by the modified lightning protection system. (X10 enlargement of 16-millimeter film)

TFSO
13 Sept. 1967
RPN 256
DT SP EXP

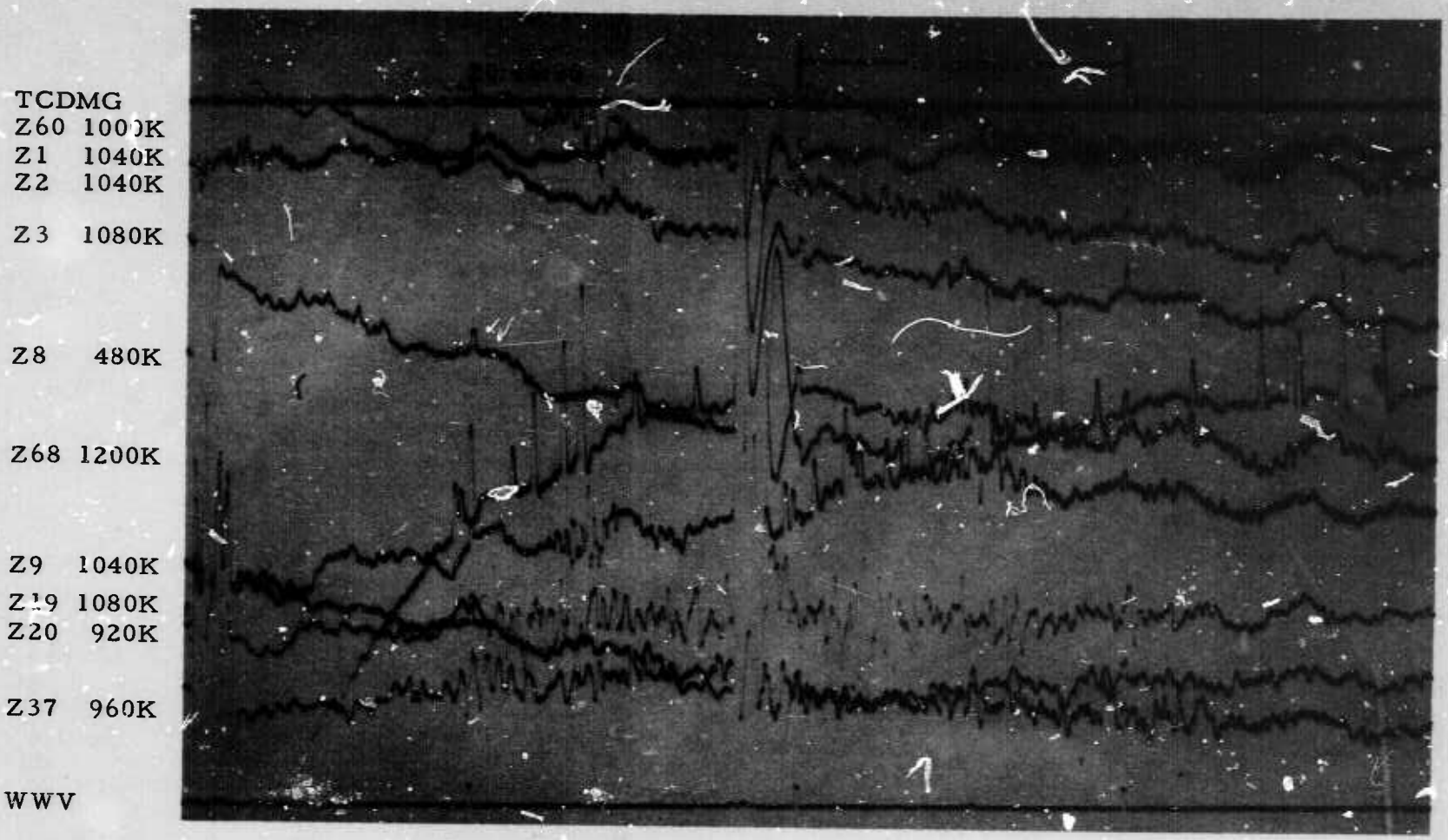

Figure 12. TFSO short-period seismogram illustrating the effects of lightning on the seismographs of the 37-element array protected by the modified lightning protection system. (X10 enlargement of 16-millimeter film)

TFSO
13 Sept. 1967
RPN 256
DT SP EXP

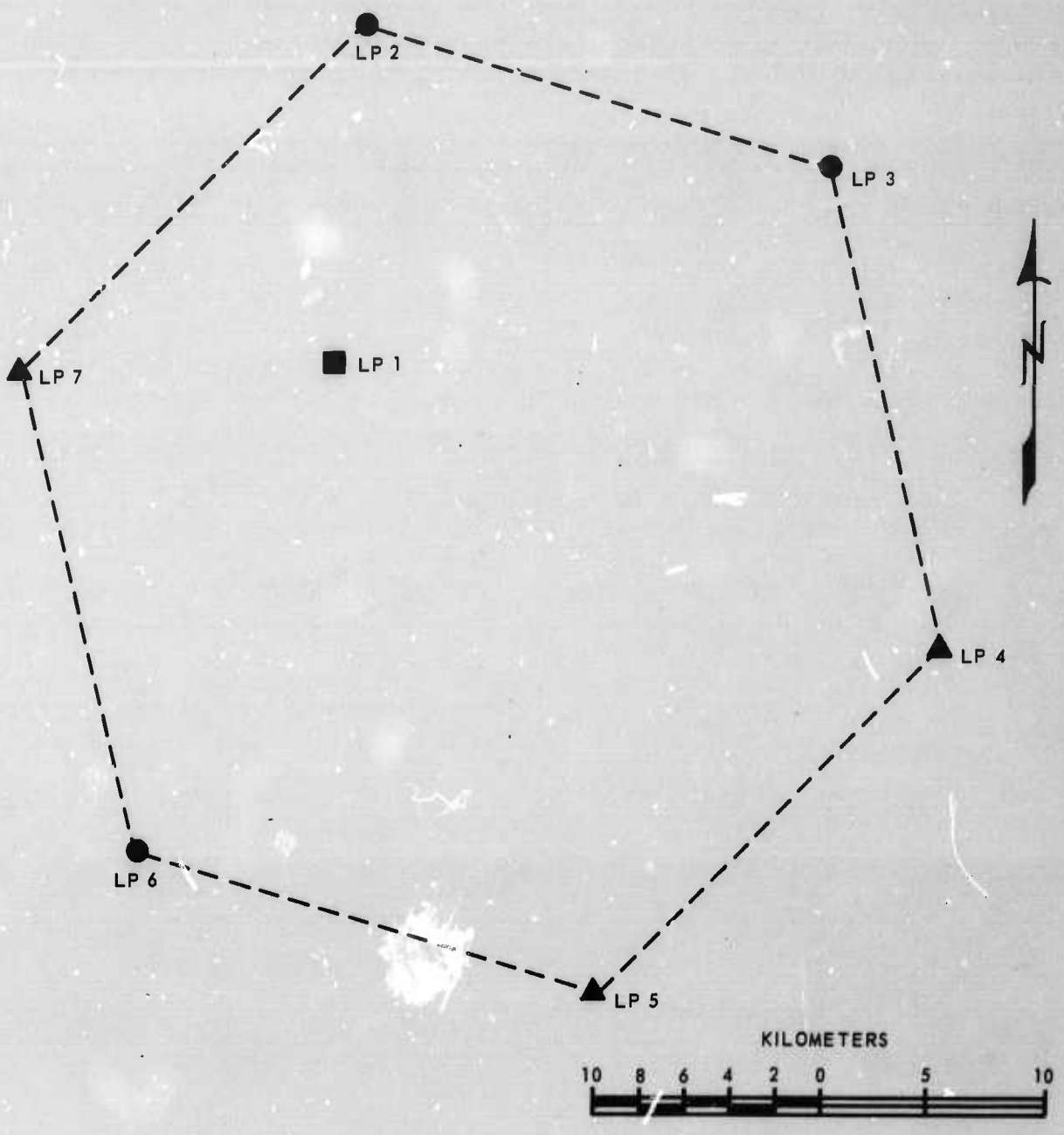

Figure 13. Planned orientation of the TFSO long-period array showing the locations of the long-period vaults and array installation status

G 3225

seismic timer, indicates that the thickness of the overburden over the granite is between 20 and 30 feet. We plan to verify this by core drilling early in October.

Final site selection of LP2, LP3, and LP6 will be accomplished in October. Presently, we plan to use the TFSO long-period vault as site LP1.

6.4.4 Data Transmission

Long-period sites LP3 and LP4 will utilize existing Mountain States Telephone Company circuits. The telephone company will probably upgrade these circuits in this area at some time in the future; however, they do not plan to do so for at least a year.

Data will be transmitted from site LP5 by a radio-microwave system; the application for FCC licensing has been forwarded to ASD.

LP1, LP2, LP6, and LP7 will utilize spiral-four cable for data transmission. Cable for these sites has been partly installed during the installation of cable for the short-period array.

APPENDIX TO TECHNICAL REPORT NO. 67-63

STATEMENT OF WORK

STATEMENT OF WORK TO BE DONE
(AFTAC Project Authorization No. VELA T/7702/S/ASD) (32)

Tasks:

a. Operation:

(1) Continue operation of the Tonto Forest Seismological Observatory (TFSO), normally recording data continuously.

(2) Evaluate the seismic data to determine optimum operational characteristics and make changes in the operating parameters as may be required to provide the most effective observatory possible. Addition and modification of instrumentation are within the scope of work. However, such instrument modifications and additions, data evaluation, and major parameter changes are subject to the prior approval of the AFTAC project officer.

(3) Conduct routine daily analysis of seismic data at the observatory and transmit daily seismic reports to the Environmental Science Services Administration, Coast and Geodetic Survey, Wash DC using the established report format and detailed instructions.

(4) Record the results of daily analysis on magnetic tape in a format compatible with the automated bulletin program used by the Seismic Data Laboratory (SDL) in their preparation of the seismological bulletin of the VELA-UNIFORM seismological observatories. The format should be established by coordination with SDL through the AFTAC project officer. The schedule of routine shipments of these prepared magnetic tapes to SDL will be established by the AFTAC project officer.

(5) Establish quality control procedures and conduct quality control, as necessary, to assure the recording of high quality data on both magnetic tape and film. Past experience indicates that a quality control review of one magnetic tape per magnetic tape recorder at the observatory during each week is satisfactory unless quality control tolerances have been exceeded and the necessity of additional quality control arises. Quality control of magnetic tape should include, but need not necessarily be limited to, the following items:

(a) Completeness and accuracy of operation logs.

(b) Accuracy of observatory measurements of system noise and equivalent ground motion.

(c) Quality and completeness of voice comments.

(d) Examination of all calibrations to assure that clipping does not occur.

(e) Determination of relative phase shift on all array seismographs.

(f) Measurement of DC unbalance.

(g) Presence and accuracy of tape calibration and alignment.

(h) Check of uncompensated noise on each channel.

(i) Check of uncompensated signal-to-noise of channel 7.

(j) Check of general strength and quality of timing data derived from National Bureau of Standards Station WWV.

(k) Check of time pulse modulated 60 cps on channel 14 for adequate signal level and for presence of time pulses.

(l) Check of synchronization of digital time encoder with WWV.

(6) Provide observatory facilities, accompanying technical assistance by observatory personnel, and seismological data to requesting organizations and individuals after approval by the AFTAC project officer.

(7) Maintain, repair, protect, and preserve the facilities of TFSO in good physical condition in accordance with sound industrial practice.

b. Instrument Evaluation: On approval by the AFTAC project officer, evaluate the performance characteristics of experimental or off-the-shelf equipment offering potential improvement in the performance of observatory seismograph systems. Operation and test of such instrumentation under field conditions should normally be preceded by laboratory test and evaluation.

c. Special Investigations:

(1) Conduct research investigations as approved or requested by the AFTAC project officer to obtain fundamental information which will lead to improvements in the detection capability of TFSO. These programs should take advantage of geological, meteorological, and seismological conditions of the observatory. The following special studies should be accomplished:

(a) Design and install an array of approximately 37 short-period vertical seismographs. This array should be about 30 kilometers in diameter. The equipment and detector sites of existing arrays should be used to the extent possible in the design of the extended array.

(b) Design and install a 7 to 10 element array of long-period seismographs. This array should be approximately 30 kilometers in diameter.

(c) Evaluate the beam-steering capabilities of both arrays.

(2) Research might pursue investigations in, but is not necessarily limited to, the following areas of interest: microseismic noise, signal characteristics, data presentation, detection threshold, and array design (surface and shallow borehole).

(3) Prior to commencing any research investigation, AFTAC approval of the proposed investigation and of a comprehensive program outline of the intended research must be obtained.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
Teledyne Industries Incorporated
Geotech Division, 3401 Shiloh Road
Garland, Texas 75040

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
Operation of the Tonto Forest Seismological Observatory
Quarterly Report No. 3, Project VT/7702
1 July through 30 September 1967

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Quarterly Report No. 3, Project VT/7702, 1 June through 30 September 1967

5. AUTHOR(S) *(First name, middle initial, last name)*
Geotech Staff

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
30 October 1967	41	None

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
AF 33(657)-67-C-0091	
b. PROJECT NO. VELA T/7702	TR 67-63
c. ARPA Order No. 624	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d. ARPA Code No.	

10. DISTRIBUTION STATEMENT
This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Chief of AFTAC.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Advanced Research Projects Agency
Nuclear Test Detection Office
Washington, D. C.

13. ABSTRACT

This is a report of the work accomplished on Project VT/7702 from 1 July through 30 September 1967. Project VT/7702 includes the operation, evaluation, improvement, and expansion of the Tonto Forest Seismological Observatory (TFSO) located near Payson, Arizona. It also includes special research and test functions carried out at TFSO and research and development tasks performed by the Garland, Texas, staff using TFSO data.

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Seismograph operating parameters						
Long-period seismograph tests						
Long-period solid-state amplifier tests						
Short-period array installation						
Long-period array installation						